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Evaluation of the Ateco "RIP-PACKER"



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EVALUATION OF THE ATECO "RIP-PACKER"
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ABSTRACT

The American Tractor Equipment Company (ATECO) "Rip-Packer" consists of a hydraulically controlled ripper assembly and a combination compaction-cutter-crusher unit. This equipment is designed to process surface rocks in place for use as base course and surfacing material on low standard, unpaved roads.

This project was initiated to determine (1) types of in place roadway material that can be effectively processed with the Rip-Packer, and (2) the relationship between the physical properties of the rock and the effectiveness of utilizing the ATECO equipment for processing these materials.

A series of field tests performed in June, 1968, on five Forest Service roads in California, established that the Rip-Packer is effective on certain types of rock, and that there are definite relationships between rock properties and equipment effectiveness.

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INTRODUCTION

One of the major maintenance problems on low standard, unpaved forest roads is the occurrence of rocks and boulders on the roadway surface. These rocks are the result of surface (cushion) material deteriorating and dissipating by the processes of wind and water erosion and the effects of traffic. Conventional means of maintaining these roads consist of either importing surfacing material or ripping and wasting the rock. Both are costly methods when compared economically to the low standard to which the road was originally constructed. Considerable savings are anticipated if the rock could be reclaimed and processed in place as base course and surfacing material.

A number of mobile units, utilizing various types of internal rock crushers, have been developed and marketed. Some of these units have been used successfully on Forest Service roads; however, the size of this type of equipment generally prohibits its use on the many narrow, winding, and steep roads in the National Forests.

The equipment investigated in this study was developed and manufactured by the American Tractor Equipment Corporation (ATECO) of Oakland, California. It consists of a hydraulically controlled ripper and a compaction-cutter-crusher (CCC) unit. ATECO refers to the combination as a "Rip-Packer".

The CCC unit is designed to mount on an ATECO tool beam for graders, dozers, loaders, and other similar types of heavy equipment and is interchangeable with the ripper teeth.

The general operating procedure for the Rip-Packer is to initially make a number of passes with the ripper assembly to lift and fracture the large rock material in the road surface. The number of passes and the number and arrangement of the teeth are dependent upon the type and condition of the material being worked. The ripper teeth are then removed, and the CCC unit is mounted on the tool beam. A number of passes are made with this unit to break up, crush, and finally compact the roadway surface. Again, the number of passes is dependent upon the material. For a complete finishing job, the blade on the grader can be used before, during, and/or after the operation with the CCC unit.

During fiscal year 1966, the Forest Service's Equipment Development Center at San Dimas, California (SDEDC) made a preliminary evaluation of ATECO's ripper and CCC combination and concluded that it was reasonably effective for "road surface maintenance" under the very limited conditions of the study; however, more data were required to determine its effectiveness on various types of rock material found on forest roads.

On the basis of the results and conclusions of this preliminary evaluation, California Region's Engineering Materials Investigations Branch (EMIB), in conjunction with the SDEDC, proposed this investigation to further evaluate the ATECO equipment. More specifically, the stated objectives of this study were to determine:

1. Types of in place roadway material that can be effectively processed with the use of ATECO ripper and CCC units mounted to motor graders;

- and
2. A relationship between the physical properties of rock materials and the effectiveness of utilizing the ATECO equipment for processing these materials.

DESCRIPTION OF EQUIPMENT

The ripper assembly used in this study was ATECO's Model HR-12 (fig. 1).



Figure 1. The mounted ripper assembly portion of the ATECO equipment

The assembly consists of a tool beam that accommodates five ripper teeth. The center-to-center distance of the teeth is 0.53 meters (21 inches), for a total ripping width of 2.13 meters (84 inches). The ripper teeth are removable and can be used in any combination up to five. The teeth are of the curved type and are capable of providing ripping depths to 0.48 meters (19 inches). The assembly was hydraulically operated and mounted on the rear of the Caterpillar Tractor Company's motor grader model CAT-12E.

The CCC unit used in this test was ATECO's Model CCC-619, Mark II (fig. 2). This model replaced the CCC-6 model ^{1/} used in the SDEDC's preliminary evaluation. The only apparent major difference between the old and new models is the number of cutter rings; the CCC-6 had 17, while the new Mark II has 19. Each of

^{1/} Ring configuration used on ATECO's CCC-6 model is now available only on the Young Corporation's "Tomahawk" unit.

the rings is 0.53 meters (21 inches) in diameter; has eight circular longitudinal cutters for scoring and splitting, plus diagonal crusher teeth for crushing, sizing, and compacting; and is made of hard, heat-treated alloy steel (fig. 3).

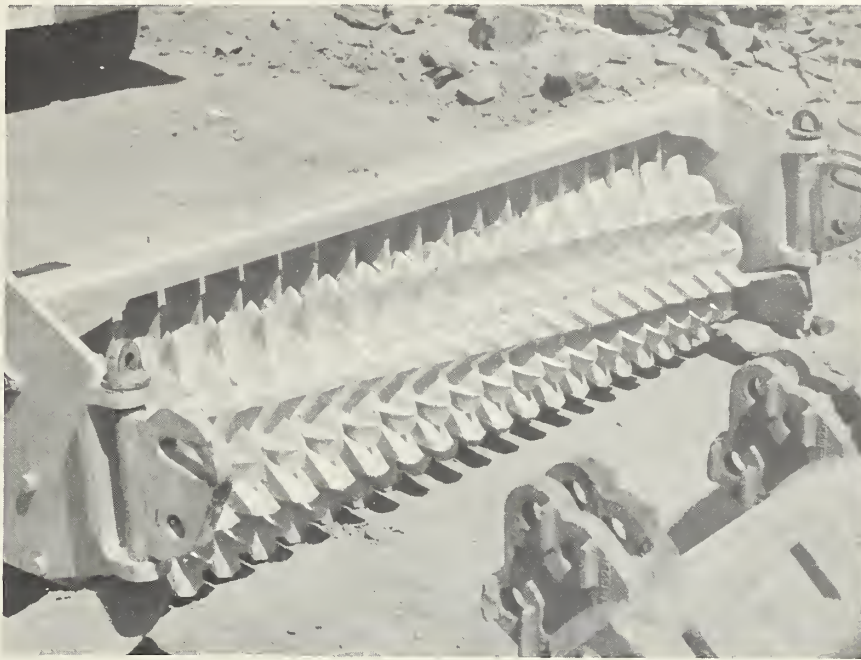


Figure 2. The compaction-cutter-crusher unit portion of the ATECO equipment. The large brackets at either end of the unit are pinned to the tool beam.



Figure 3. A close-up of the cutter rings of the CCC unit.

The CCC is designed to mount on the tool beam in place of the ripper teeth. It can be worked in both forward and reverse directions, eliminating the requirement for turning the equipment around. The unit's overall length is 2.36 meters (93 inches) and works a 1.83-meter (6-foot) swath of roadway section. The overall depth is 0.84 meters (33 inches) and the overall height, 0.84 meters. The unit weighs 11.57 kilonewtons (2,600 pounds).

TEST PLAN

The test plan established that the EMIB and the SDEDC would conduct this study jointly. The EMIB was responsible for selecting the roads and materials to be tested, classifying and performing laboratory tests on the materials, developing the work plan, coordinating the study with the equipment manufacturer and the various Forest Service personnel involved, conducting the field tests, and writing the report. The SDEDC was to assist in preparing the test and work plans, conducting the actual field tests, and writing the final report. In addition, the SDEDC was directly responsible for instrumenting and observing the equipment for the purpose of evaluating its mechanical performance, providing the necessary photographic efforts, and preparing the final report for publication.

For the initial phase of the test, the EMIB investigated and sampled various roads in the California Region, determining locations where it would be feasible to conduct the field tests. The samples were processed and tested in the EMIB Materials Testing Laboratory to classify the materials according to their physical properties. On the basis of these results, five sites were selected for the field tests, such that rock types with physical characteristics varying from the softest to the hardest could be tested. In addition, other items considered in this selection were terrain, geological source of the rock, quantity of rock on the road surface, and actual degree of maintenance problems caused by the existence of these surface rocks. The names and locations of the roads and the geologic classification and certain physical properties of the rocks found on these roads are shown in Table 1 of the Appendix.

A CAT-12E grader equipped with an ATECO tool beam and a new CCC unit was obtained for the test. The owner-operator of the grader had had extensive experience with the Rip-Packer before the test. A section of each road was tested in accordance with the work plan. The length of each section was 396 meters (1,300 feet, or approximately $\frac{1}{4}$ mile). Except on extremely wide roads, the entire roadway width was worked. Initial samples were obtained at locations specified by the EMIB Engineer-In-Charge (EIC) of the project. The number and exact location of the sampling points were predicated on obtaining sufficient samples that would represent as nearly as possible all the material in the test section. The samples were obtained to a depth of 0.15 meters (6 inches). Each was screened at the test site, using a portable mechanical sieve-shaker. The sizes selected for the gradation determinations ranged from material retained on the 203.2-mm (8-inch) sieve to that passing a 4.76-mm (No. 4, or slightly less than $\frac{1}{4}$ -inch diameter) sieve.

In order to ascertain the effects of moisture on the road during this type of operation, part of the section was watered. The remainder was tested in its natural moisture condition.

Following initial sampling, the roadbed was ripped over the entire length of the section. The road was then sampled and the material sieved in the same manner as before, and the CCC unit was installed on the grader. The road was then worked with this unit, and again samples were obtained for the purpose of determining gradations after each group of four passes. The total number of passes for each section was established by the EIC during the test. In addition to the gradation determinations, other qualitative and quantitative evaluations were made, such as time required for each pass, visual condition of the road surface after each series of passes, effect of road grade on operations, and the effects of operating the ATECO equipment on certain mechanical parts of the grader.

Following the field test, all data were correlated; and conclusions relating to the stated objectives were ascertained.

TEST RESULTS

Sixteen roads on six National Forests in Northern California were investigated and sampled by EMB personnel in the fall of 1967. Material from each road was classified according to its geologic source, and the following ASTM standard laboratory tests were performed on the samples:

1. Resistance to Abrasion of Coarse Aggregates by Use of the Los Angeles Machine (ASTM Designation C535-65)
2. Specific Gravity and Absorption of Coarse Aggregate (ASTM Designation C127-59)
3. Specific Gravity of Fine Aggregate (ASTM Designation C128-59)
4. Sieve Analysis of Fine and Coarse Aggregates (ASTM Designation C136-63 and C117-66)

Although results of all the laboratory tests were considered, the final selection of the test roads was based primarily on the geological classification of the rock and the results of the resistance to abrasion by use of the Los Angeles Machine, commonly referred to as the Los Angeles Rattler Test, or LART. LART values range from 0 to 100, with the lower values indicating a greater resistance to abrasion. In addition to its primary purpose, this test also gives an indication of the relative hardness of the material. As there are at present no acceptable test methods available to quantitatively determine the hardness (or resistance to crushing) of rock, the LART results of the materials sampled were used as a guideline in determining this physical property. Materials from the initial 16 sites investigated produced LART values ranging from 12 (very hard volcanic material on the Tahoe National Forest) to 67 (a highly weathered granite on the Stanislaus). These two roads, plus three others containing material of intermediate LART values, were chosen for the field study.

During the actual field test, new samples of the rock were obtained and tested again for LART values to insure that the material had not changed appreciably from that sampled in the fall. Of the five sites tested, the material in only one, the Beardsley Road, had significantly different physical characteristics. Between the time of the

initial sampling and the actual field test, this section of road had been improved by the addition of an import material which completely covered the exposed rock. Therefore, the decision was made during the field test to change the site to an unimproved portion of the same road in the hope that the rock on this new section had physical characteristics similar to those previously sampled. However, the laboratory results showed that the LART values of the new material was much lower (35) than the original (67) resulting in significant reduction in the range of LART values for materials tested.

Cottonwood Road

The field test began in June, 1968, and initially proceeded as outlined in the test plan. The Cottonwood Road on the Stanislaus National Forest was the first one tested. The material on this road consisted primarily of schist with a LART value of 34.4, and there were outcroppings of rock up to 300 mm (12 inches) in diameter. The section of road tested had a grade averaging approximately 5 percent, was 396 meters ($\frac{1}{4}$ mile) long and 6.0 meters (20 feet) wide. Half the road (198 meters or $\frac{1}{8}$ mile) was watered, and the remaining half was left in its natural moisture condition. The entire section was ripped by using two ripper teeth, and rocks having diameters larger than 250 mm (10 inches) were side-cast by using the blade (fig. 4).

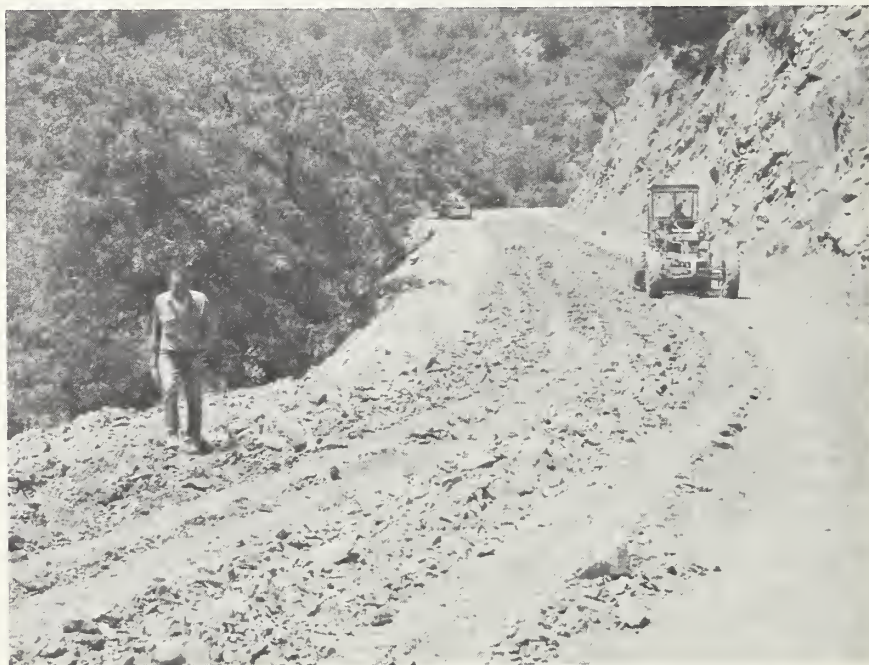


Figure 4. Ripping operations on the Cottonwood Road

Sixteen passes were made with the ripper. The CCC unit was then mounted on the motor grader and 16 passes were made with this unit (fig. 5). Samples of material were taken after each series of four passes. It was noted during the test, however, that there was very little improvement after the first eight passes. The final opera-

tion consisted of finishing the road surface with the motor grader blade.

It was also noted that the CCC unit appeared to break most of the large rock with little difficulty; however, in a few spots the CCC unit would tend to push or "punch" the rocks into the road surface instead of crushing or breaking them.

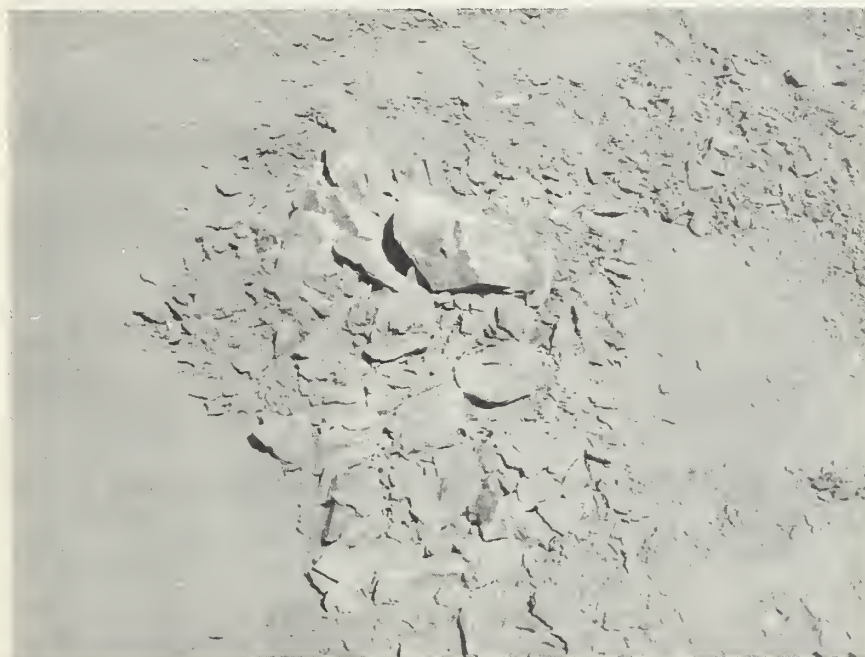


Figure 5. A small pile of rocks broken after the first pass of the CCC unit on the Cottonwood Road

The overall condition of the road surface after completion of the project was considered to be significantly improved over the portion of the road not worked with the ATECO equipment. It was also noted that the watered section of the test road appeared to be in much better condition than the unwatered portion. The results of the progressive gradation determinations are shown in Table 2a of the Appendix.

Beardsley Road

The second road tested was the Beardsley Road, also located on the Stanislaus. The rock in this section, primarily a river-run granite, was much smaller than that on the Cottonwood Road. Most of the rock on the surface was 76 mm (3 inches) or smaller, with a relatively short (30-meter or 100-foot) section containing 380- to 510-mm (15- to 20-inch) diameter outcroppings of a micaceous granite that was soft enough to crumble by hand. (A sample of material sent to the lab and tested had a LART value of over 80). In addition, the road had another small section that contained a 51-mm (2-inch) thick asphalt oil cake that was badly broken and potholed and apparently had been there for a substantial period of time. This road actually had been built on top of a railroad grade, and much of the smaller rock on the surface

was from the old ballast material. The road, for the most part, was level and approximately 6.1 to 7.6 meters (20 to 25 feet) wide; however, only a 3.0-meter (10-foot) wide section of the road was worked by the Rip-Packer (fig. 6).



Figure 6. CCC operations on the Beardsley Road

The road was ripped by using three ripper teeth, and this operation exposed a few larger rocks in the harder granite sections. As in the previous test section, half the road was watered, while the other half was left in its natural moisture condition. Although a total of 16 passes was made with the CCC unit, little increase in breakage of rock was noted after the first four passes.

It was determined during the observations of the test program that the CCC unit, as expected, crushed the soft micaceous granite completely and was very effective in crushing and compacting the caked asphalt section of the road. The unit broke and crushed the majority of the larger granitic rocks ripped to the surface but was very ineffective in breaking the smaller 76-mm (3-inch) diameter surface material. Because of the very small number of large rocks brought to the surface, the gradation results in Table 2b reflect only the results of the CCC unit on the smaller rocks. The apparent small increase of larger material after processing, indicated in this Table, is attributed to the random sampling procedures used. Two reasons for the inability of the CCC unit to effectively break the smaller rocks are the size and smoothness of the river-run material. Because of the small size of the rock, the cutting edges of the CCC unit would either push the rocks aside or drive them into the ground, while the lack of rough surface or angular edges caused the cutting teeth to "slip off" the rock. On this particular road, water had very little effect on the operation.

Texas Hill Road

The third road, the Texas Hill Road on the Tahoe National Forest, contained a mixture of volcanic and granitic rock of the river-run variety. The material, as shown in Table 1, was somewhat harder (LART value of 12.0) than the material in the two previous roads tested. The Texas Hill Road was essentially flat, with a few large radius curves (fig. 7). The surface consisted of a considerable amount of small 76-mm (3-inch) diameter rock, with many outcroppings of larger rock.



Figure 7. The original surface of the Texas Hill Road

A change was made in the test plan to determine the effect of working the CCC unit on a section of road which had not been previously ripped. Therefore, only half the test section was ripped prior to working with the CCC unit while the remaining half was left in its natural state before using the CCC unit. The section selected for ripping was ripped by using first two, then three teeth (fig. 8).

A large number of oversize rocks, greater than 250 mm (10 inches) in diameter, were brought to the surface during the ripping operation and in turn were side-cast with the motor grader. However, it was impossible to selectively remove the large rocks without also removing a significant quantity of fine-grained material from the surface. A total of 16 passes was made on the ripped section, with little breakage of rock. The rock was obviously too hard and the ground too soft for the CCC unit to handle effectively, and the only result of the operation was that rocks were punched into the roadway surface.

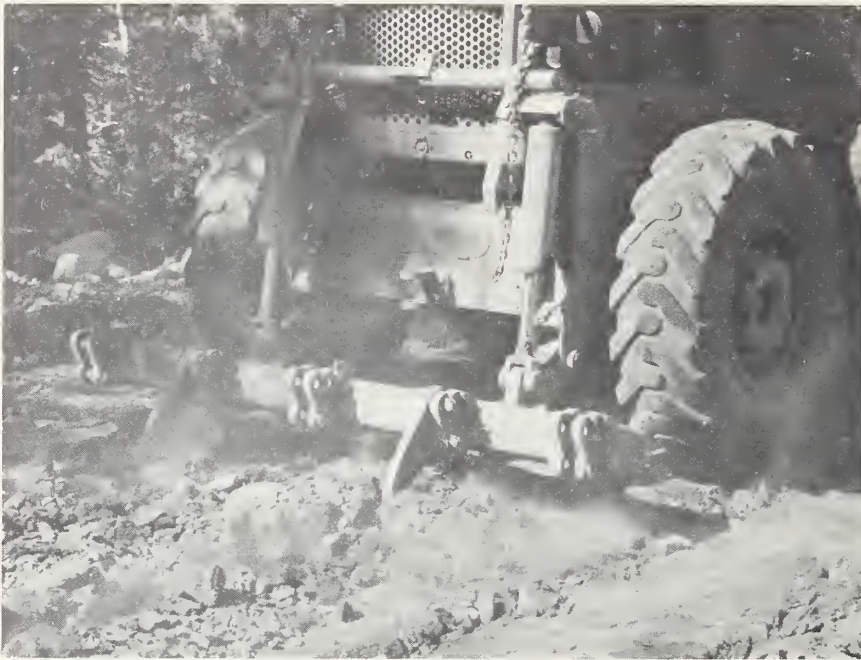


Figure 8. The ripping operation on the Texas Hill Road. Note the large rocks exposed which were originally just below the road surface.

After only four passes with the CCC unit on the unripped portion of the test section, it was apparent that continued passes would have little if any effect on the condition of the rock on the road. During these few passes, the only significant effect of the CCC unit was to "chip off" a small amount of material at the edges of the rocks. In a few isolated cases, a rock was split; but further passes had little effect on the broken pieces.

Gradation results for this road are shown in Tables 2c and 2d of the Appendix.

After the undisturbed surface processing proved ineffective, the CCC unit was moved to an area where the rock in the berm was bladed onto well-compacted, undisturbed base material. After numerous CCC passes at varying speeds, this method of processing the material also proved to be ineffective. From visual inspection, it was estimated that the rock broken amounted to approximately 30 percent; but this could be misleading because individual rocks showing breakage fractured into only two pieces during the entire operation, and further breakdown of material was impossible to obtain. The largest percentage of breakage occurred during the first four passes, and further processing with another 15 passes of the CCC proved to be ineffective.

Fordyce Road

The fourth test site was located on the Tahoe National Forest's Fordyce Road. The road surface contained large amounts of rock material, primarily granitic with some volcanic. The size of the rocks ranged from 25-mm (1-inch) to as large as 460- to

510-mm (18 to 20 inches) in diameter, with the majority being in the 100- to 200-mm (4- to 8-inch) range (fig. 9).



Figure 9. The original surface of the Fordyce Road

The material was mostly river-run, and therefore the rocks were rounded and very smooth and had a LART value of 20.4. The road was relatively steep (10 to 15 percent grade) and narrow (2.4 to 3.0 meters, or 8 to 10 feet, wide) and contained short radius curves. Due to the high field moisture content in the road, which appeared to be in excess of optimum, it was decided to forego the previous procedure of watering a portion of the test strip.

Because of the large amount of rock imbedded in the surface, the ripping operation was extremely difficult. Two teeth were used on the first pass, three thereafter; and secondary ripping was required in most portions of the test strip. Numerous large rocks (300-mm or 12-inch diameter and greater) were exposed during this operation and side-cast with the blade. Due to the obvious inability of the CCC unit to effectively crush the rock, operations were stopped after the first four passes. The little breakage and crushing that occurred resulted during the initial pass. The rock was definitely too hard for the CCC unit to handle by the usual methods. To obtain a usable road surface required a combination of ripping, side-casting large boulders, punching the small rock into the loosened surface with the CCC unit, and blading. Although the ATECO equipment was unable to break and crush the rock as expected, this method of operation produced a road surface of better quality than had existed prior to the test. The results of the grading tests are shown in Table 2e of the Appendix.

Magonigal Road

The last site tested, also on the Tahoe National Forest, was the Magonigal Road. This was very similar to the previous road except that it contained more volcanic than granitic material. Because of the inability of the CCC unit to break or crush similar rock on the two previous sites in this general area, it was decided that, prior to ripping this section, some preliminary testing would be performed. First, rocks from the large roadway berms were bladed onto a hard-packed, undisturbed section of roadway. After several passes were made with the CCC unit and only a minor amount of material had broken up, the rock was again bladed onto a firm base in a controlled windrow; and further processing was attempted (fig. 10).



Figure 10. Surface rock being worked into a windrow on the Magonigal Road

After completion of 18 passes by the CCC unit, it was obvious that rock on this roadway could not be broken or crushed under ideal conditions — controlled windrows, firm base for impact, etc. — and that further testing of this section as previously planned would prove to be wasted (fig. 11).

It was then decided to perform special tests on two areas located on another section of the road. These areas contained material visibly different from the material previously tested.

The first section consisted of granitic and volcanic material that was angular and rough, in contrast with the previously tested river-run material. Surface material was processed with the CCC unit, in place on a firm, undisturbed base. All of the granitic material was effectively crushed, but only a small amount of the volcanic

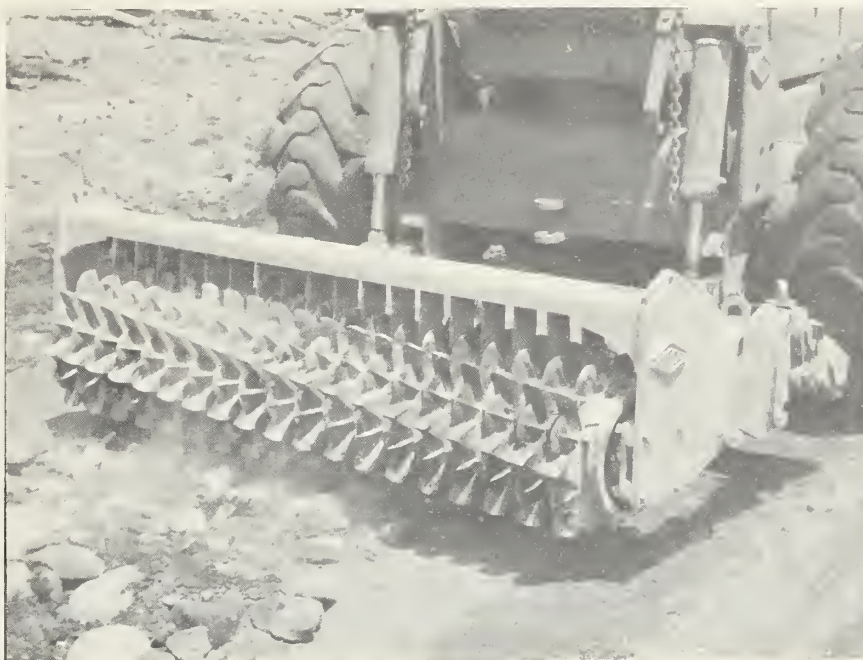


Figure 11. Results of processing the windrows on the Magonigal Road with the CCC unit. Note the lack of visible rock breakage.

rock could be broken. Samples of each of the materials were tested later, and LART values of 27 for the granite and 14 for the volcanic material were determined. The second site contained a mixture of varied materials (granite, shale, volcanic material) hand-picked from areas adjacent to the roadway and placed on a rocky base for testing. All of the material was irregular in shape, and approximately 90 percent breakage was obtained. The small amount of volcanic material again appeared from visual inspection to be too hard for the CCC unit to effectively process. A LART value of 23 was later determined on a composite sample of material from this test section.

SUMMARY OF RESULTS

Due to the nature of the test program, the results are summarized in two categories, (1) operational, and (2) mechanical. The operational results refer to the effect of the equipment on processing rock material and the mechanical results refer to the effect of the operation on the mechanical performance of the equipment.

Operational

The CCC unit was very effective in crushing and breaking the material (LART value of 34) on the Cottonwood Road (Table 2a), increasing the percentage of fine materials (material passing the 4.76-mm or No. 4 sieve) from 40 to 61 and reducing the material greater than 50.8 mm (2 inches) from 20 percent of the total to only 6 per-

cent after eight passes. As was noted in the text and verified in Tables 2c, 2d, and 2e, material on the Texas Hill (LART of 12.0) and Fordyce (LART of 20.4) Roads could not be effectively crushed with the unit. The material on the Magonigal Road (LART of 19.4) was too hard to be broken, even under the ideal conditions of controlled windrows on a hard base.

Although the material on the Beardsley Road exhibited a rather high LART value of 35.1, the CCC unit was ineffective in breaking the rock (Table 2b). The reason for this is attributed to the small size (38.1 to 50.8 mm, or $1\frac{1}{2}$ to 2 inches) and the smooth texture of the river-run material. This was substantiated by the fact that the few larger, rougher textured rocks of the same material found on the road were effectively processed. In addition, a short section of micaceous granitic outcroppings (LART value of 80) on this road was completely crushed and compacted.

On the roads where the CCC unit was unable to crush the rock, an improved road surface was obtained by the procedure of ripping the roadbed, wasting the large 250-mm (10-inch) or greater rocks with a blade, punching or forcing the small rocks into the road surface with the ATECO CCC unit, and watering and final blading of the surface. Although the resulting surface after this procedure is of better quality, the effects are only temporary since once the processes of wind and water erosion and traffic action start, the resulting loss of material from the surface will again expose the rock and the condition will revert to that prior to the maintenance effort. The time element involved here, however, has not yet been ascertained. Hence the economic value of the ATECO equipment in this type of maintenance procedure is unknown.

The procedure of watering in conjunction with the use of the ATECO equipment appears to have some merit. The watering operation has two benefits; first, it reduces the amount of fines lost as a result of "dusting" during the ripping and CCC operations and, second, it aids in the compaction process of the CCC unit. The amount of water to be used should depend upon the condition of the road (for example, percentage of fines, density, moisture content). However, a moisture content near optimum, as determined by moisture-density tests, would probably give the best results.

It appears from this study, that for the most effective operations, the ripper attachment should be used in conjunction with the CCC unit. However, there are certain conditions where the unit will be more effective if used on undisturbed road surfaces. One such condition would be a road with an exceptionally high number of boulders or large rocks just below the surface which would create more problems if ripped to the surface. In this case, the importing of additional fines may be required if the number of surface rocks is insufficient to produce an adequate amount of fine material.

In addition to its rock-crushing capabilities, it was determined during the study that the Rip-Packer has potential for processing deteriorated oiled road surfaces. On the Beardsley Road, the CCC unit effectively crushed and compacted with very little effort a surface consisting of a broken oil pavement.

From an operational standpoint, this study showed that most of the improvements in the road surface resulted after the first few passes with the CCC unit. Very little,

if any, change was noted after six to eight passes, regardless of what type of material was being processed. The time and motion studies showed that the ripping speeds varied from 30.5 to 50.3 meters (100 to 165 feet) per minute, depending upon the road condition, with approximately four passes utilizing three teeth required for a 3.0-meter (10-foot) wide section. The speed used for the CCC unit operation ranged from 91.4 to 113 meters (300 to 370 feet) per minute (see Table 3). It should be noted that these times were established by an operator having considerable experience in using this equipment and that rates for effective operation by less experienced personnel would be somewhat lower.

Mechanical

No mechanical failures of any type were experienced. It was the general opinion of Forest Engineering personnel present at the test that the CCC unit was tough on equipment. However, no one felt that it was any harder on the grader than were the normally mounted hydraulic rippers.

The long pins that attach the CCC to the ripper bar (fig. 12) worked out of their sockets several times. They are presently retained in place by a cotter pin which has a tendency to fall out and get lost. A better pin-retaining device should be developed. San Bernardino National Forest personnel who operate several ATECO units have developed a method for locking the pins which they consider greatly superior to ATECO's method (fig. 13).



Figure 12. ATECO's attachment method



Figure 13. Improved attachment method

The hydraulic pressure in the rams that activate the Rip-Packer was monitored for some of the tests, using the instrumentation system shown in Figure 14. The heart of this system is a Pace-Wianco type P2 3086 pressure transducer. The hydraulic connection of this pressure transducer was fed into the line which supplies hydraulic fluid to the main rams. The transducer's input was provided by an Eico 28-volt power supply, which was in turn supplied by a Honda E300 110-volt AC generator. The output of the transducer was fed to a CEC type 5-124 light beam oscillograph. This instrument provides almost immediate response to any transient signals; thus, abrupt peaks in hydraulic pressure were easily recorded. The oscillograph, too, was powered by the Honda generator. This instrumentation system provided a continuous record of pressure in the hydraulic system during a given run.

The pressure at the inlet of the rather long hydraulic hose which supplies the hydraulic rams with fluid might not have faithfully followed the pressure in the rams. However, since the intent of this experiment was to determine the relative magnitude of pressure surges in the hydraulic system under different operating conditions, this was not thought to be a serious limitation.

Table 4 summarizes the data. Note that, with the hydraulic accumulator valve open, the rapid pressure variation due to the CCC striking rocks was approximately 1,000 psi (peak to peak) and in no case exceeded pressures normally encountered during blading and ripping. With the accumulator valve closed, the maximum pressure variation went as high as 2,600 psi. It is suggested, therefore, that during CCC operations the hydraulic accumulator valve be left open, since no increase in effectiveness of rock-breaking was observed when this valve was closed.

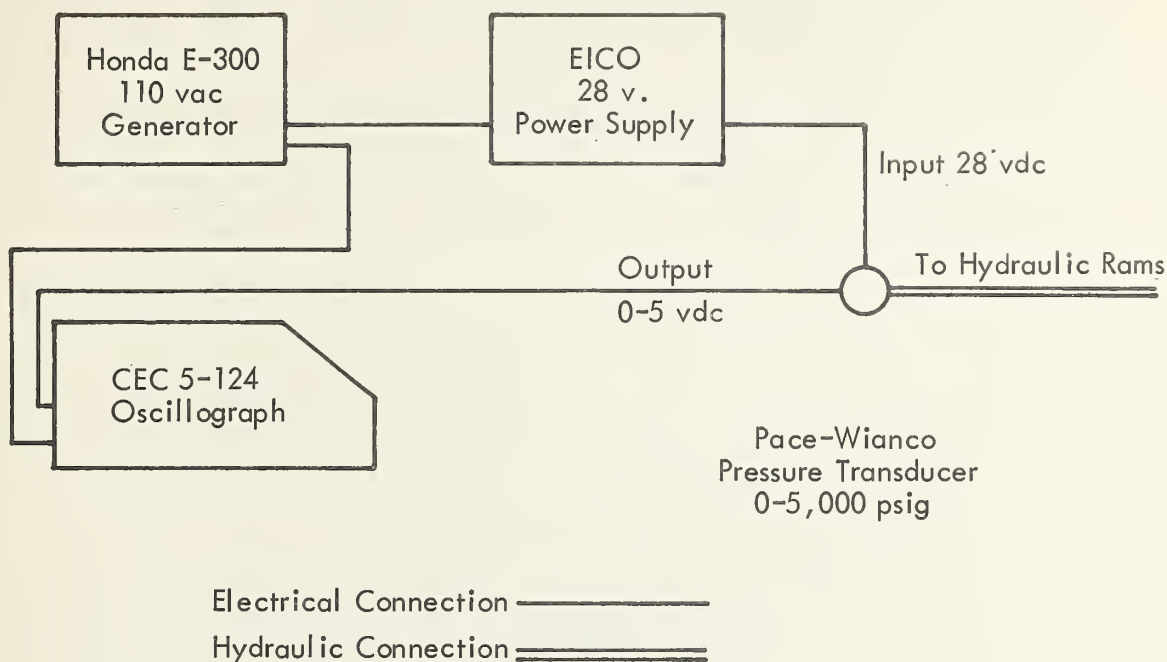


Figure 14. Instrumentation system

CONCLUSIONS

The results of this investigation led to several conclusions which are enumerated below:

1. It was determined that the Los Angeles Rattler Test is an effective and valid criterion for relating rock material and the effectiveness of the CCC unit.
2. Rock with LART values of less than 25 cannot be effectively crushed with this unit.
3. The effectiveness of the CCC unit on crushing rock with LART values greater than 25 is dependent upon the surface condition and shape of the rock. Rocks that are highly angular and have rough surfaces can be crushed if they have a LART value of 25 or greater, while the LART value requirement progressively increases for the smoother and more rounded rocks.
4. The CCC unit is most effective on rocks having diameters in the range of 75 to 250 mm (3 to 10 inches).
5. For the most efficient operation, the number of passes with the CCC unit should be limited to the range of 6 to 8.

6. The Rip-Packer, in conjunction with a motor grader, can in many cases be used effectively on roads where the rock is too hard to crush, by ripping the road surface, forcing the rock into the ripped surface, and shaping with the blade.
7. The Rip-Packer can effectively crush and compact deteriorated oil pavements.
8. The CCC unit did not appear to be harder on the grader than the normally mounted hydraulic rippers.

APPENDIX

APPENDIX

TABLE 1 – ROAD DATA AND PHYSICAL PROPERTIES

| | | | | | |
|---------------------------|------------|------------|------------|---------|-----------|
| Road name | Cottonwood | Beardsley | Texas Hill | Fordyce | Magonigal |
| Road number | 01N04 | 04N08 | 17N25 | 17N16 | 17N15 |
| Forest | Stanislaus | Stanislaus | Tahoe | Tahoe | Tahoe |
| Geologic classification | Schist | Granite | Volcanic | Granite | Volcanic |
| LART value | 34.4 | 35.1 | 12.0 | 20.4 | 19.4 |
| Specific gravity - coarse | 2.68 | 2.70 | 2.71 | 2.59 | 2.68 |
| Specific gravity - fine | 2.73 | 2.68 | 2.79 | 2.56 | 2.67 |
| Absorption, % | 1.52 | 1.08 | 0.68 | 2.20 | 0.48 |

TABLE 2a - GRADATION RESULTS

Cottonwood Road

| Number of passes with CCC unit* | % Passing | | | | |
|------------------------------------|-----------|-----|-----|-----|-----|
| | 0 | 4 | 8 | 12 | 16 |
| <u>Sieve size</u> | | | | | |
| 203.2 mm (8 in.) | 100 | 100 | 100 | 100 | 100 |
| 152.4 mm (6 in.) | 97 | 99 | 100 | 100 | 100 |
| 101.6 mm (4 in.) | 89 | 97 | 100 | 100 | 100 |
| 76.1 mm (3 in.) | 85 | 93 | 96 | 97 | 98 |
| 50.8 mm (2 in.) | 80 | 88 | 94 | 95 | 97 |
| 38.1 mm (1½ in.) | 77 | 85 | 90 | 92 | 95 |
| 19.0 mm (¾ in.) | 62 | 74 | 82 | 83 | 86 |
| 9.51 mm (3/8 in.) | 47 | 63 | 71 | 72 | 74 |
| 4.76 mm (No. 4) | 40 | 55 | 61 | 63 | 63 |

*Average of four sample sites

Geologic classification - schist

LART value - 34.4

TABLE 2b - GRADATION RESULTS

| Number of passes with CCC unit* | Beardsley Road | | | | |
|------------------------------------|----------------|-----|-----|-----|-----|
| | % Passing | | | | |
| | 0 | 4 | 8 | 12 | 16 |
| <u>Sieve size</u> | | | | | |
| 203.2 mm (8 in.) | 100 | 100 | 100 | 100 | 100 |
| 152.4 mm (6 in.) | 100 | 100 | 100 | 100 | 100 |
| 101.6 mm (4 in.) | 100 | 100 | 100 | 100 | 100 |
| 76.1 mm (3 in.) | 100 | 100 | 100 | 100 | 100 |
| 50.8 mm (2 in.) | 99 | 100 | 100 | 100 | 100 |
| 38.1 mm (1½ in.) | 95 | 96 | 97 | 96 | 97 |
| 19.0 mm (¾ in.) | 80 | 79 | 80 | 77 | 74 |
| 9.51 mm (3/8 in.) | 69 | 67 | 69 | 67 | 64 |
| 4.76 mm (No. 4) | 62 | 60 | 62 | 60 | 58 |

*Average of four sample sites

Geologic classification - granite

LART value - 35.1

TABLE 2c - GRADATION RESULTS

Texas Hill Road - ripped portion

| Number of passes with CCC unit * | % Passing | | | | |
|-------------------------------------|-----------|-----|-----|-----|-----|
| | 0 | 4 | 8 | 12 | 16 |
| <u>Sieve size</u> | | | | | |
| 203.2 mm (8 in.) | 100 | 100 | 100 | 100 | 100 |
| 152.4 mm (6 in.) | 100 | 100 | 100 | 100 | 100 |
| 101.6 mm (4 in.) | 96 | 100 | 100 | 100 | 100 |
| 76.1 mm (3 in.) | 88 | 95 | 99 | 100 | 100 |
| 50.8 mm (2 in.) | 83 | 87 | 94 | 98 | 96 |
| 38.1 mm (1½ in.) | 77 | 79 | 84 | 94 | 88 |
| 19.0 mm (¾ in.) | 64 | 67 | 71 | 81 | 76 |
| 9.51 mm (3/8 in.) | 52 | 55 | 60 | 68 | 64 |
| 4.76 mm (No. 4) | 43 | 44 | 49 | 57 | 54 |

*Average of two sample sites

Geologic classification - volcanic

LART value - 12.0

TABLE 2d - GRADATION RESULTS

Texas Hill Road - unripped section

| Number of passes with CCC unit* | % Passing | | | | |
|------------------------------------|-----------|-----|---|----|----|
| | 0 | 4 | 8 | 12 | 16 |
| <u>Sieve size</u> | | | | | |
| 203.2 mm (8 in.) | 100 | 100 | | | |
| 152.4 mm (6 in.) | 100 | 100 | | | |
| 101.6 mm (4 in.) | 98 | 100 | | | |
| 76.1 mm (3 in.) | 93 | 100 | | | |
| 50.8 mm (2 in.) | 87 | 93 | | | |
| 38.1 mm (1½ in.) | 82 | 89 | | | |
| 19.0 mm (¾ in.) | 68 | 77 | | | |
| 9.51 mm (3/8 in.) | 52 | 63 | | | |
| 4.76 mm (No. 4) | 38 | 50 | | | |

*Average of two sample sites

Geologic classification - volcanic

LART value - 12.0

TABLE 2e - GRADATION RESULTS

| Number of passes with CCC unit* | Fordyce Road | | | | |
|------------------------------------|--------------|-----|---|----|----|
| | % Passing | | | | |
| | 0 | 4 | 8 | 12 | 16 |
| <u>Sieve size</u> | | | | | |
| 203.2 mm (8 in.) | 100 | 100 | | | |
| 152.4 mm (6 in.) | 90 | 100 | | | |
| 101.6 mm (4 in.) | 78 | 95 | | | |
| 76.1 mm (3 in.) | 72 | 91 | | | |
| 50.8 mm (2 in.) | 65 | 78 | | | |
| 38.1 mm (1½ in.) | 61 | 73 | | | |
| 19.0 mm (¾ in.) | 52 | 60 | | | |
| 9.51 mm (3/8 in.) | 42 | 48 | | | |
| 4.76 mm (No. 4) | 33 | 39 | | | |

*Average of four sample sites

Geologic classification - granite

LART value - 20.4

TABLE 3 – SPEED RATE OF OPERATIONS

| Road | Grade % | Rip Speed | | CCC Speed | |
|------------|------------|----------------------------|----------------------------|----------------------------|----------------------------|
| | | Upgrade | Downgrade | Upgrade | Downgrade |
| Cottonwood | 5 | 43.9 m/min (144 ft/min) | 49.7 m/min (163 ft/min) | 96.3 m/min (316 ft/min) | 91.1 m/min (299 ft/min) |
| Beardsley | 0 | 32.9 m/min (108 ft/min) | 32.9 m/min (108 ft/min) | 109 m/min (359 ft/min) | 109 m/min (359 ft/min) |
| Texas Hill | 0 | 36.6 m/min (120 ft/min) | 36.6 m/min (120 ft/min) | 91.4 m/min (300 ft/min) | 91.4 m/min (300 ft/min) |
| Fordyce | 10-15 | * | 39.6 m/min (130 ft/min) | * | 113 m/min (370 ft/min) |

*Ripped and crushed downgrade only

TABLE 4 - HYDRAULIC SYSTEM PRESSURE VARIATIONS

Mean Pressure 200-700 psi

| Site and operating mode | Average peak-to-peak variation, psi | |
|--------------------------------|---|--------------------|
| | Accumulator open | Accumulator closed |
| Cottonwood Road, CCC operating | 1,200 psi | - |
| Beardsley Road, CCC operating | 800 psi | - |
| Texas Hill Road, ripping | - | 1,700 psi |
| " " " , CCC | 850 psi | 1,600 psi |
| Magonigal Road, CCC | 1,400 psi | 2,000 psi |
| Fordyce Road, blade | - | 1,200 psi |
| " " , rip | - | 1,700 psi |
| " " , CCC | 1,800 psi, occasional excursions to 2,000 psi | 2,600 psi |

